Juvenile Instability in Planted Pines

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SUMMARY

Planted pines often require a number of years to achieve a firm anchorage. In this, they differ from naturally established trees which, at least to begin with, are usually quite stable. This difference is due to the effect of the usual methods of raising and planting forest tree seedlings on root morphology. One way to eliminate this effect is to plant seedlings while they are very young and still retain the capacity to initiate first order lateral roots. Another, is to use planting stock raised in containers coated with a root growth inhibitor to prevent the elongation of lateral roots until after planting. With both methods, planted trees can be obtained having a symmetrical array of primary lateral roots comparable in form and mechanical function to the roots of a naturally established tree.

INTRODUCTION

Planted pines often require a number of years to achieve a firm anchorage during which time they may easily be blown over by the wind or weighed down by snow (Bergman, 1976; Bell, 1978; Booth and Mayhead, 1972; Chavasse, 1978; Clarke, 1956; Edwards, Atterson and Howell, 1963; Moss, 1971). Trees thus affected are not uprooted and so continue to grow. However, they acquire a geotropic stem curvature or sweep which, under present or foreseeable market conditions, greatly reduces their value (Moss, 1971).

On approaching maturity, planted pines frequently become unduly susceptible to windthrow (Bergman, 1976; Irvine, 1970; Moss, 1971) and there is evidence to suggest that this development has some relationship to instability during the juvenile phase (Moss, 1971).

Thus, in the plantation culture of pines, the instability of young trees is a matter of considerable practical significance.

In this article the cause and consequences of juvenile instability in planted pines, and also possible means to prevent it, are examined with particular reference to experience with lodgepole pine (*Pinus contorta* Dougl.) in British Columbia.

THE CAUSE OF JUVENILE INSTABILITY

In some cases, instability in planted pines may be the result of a species or a provenance having been planted on a site to which it is not well adapted. In support of this interpretation it has been suggested that the instability of radiata pine (*P. radiata* D. Don) in

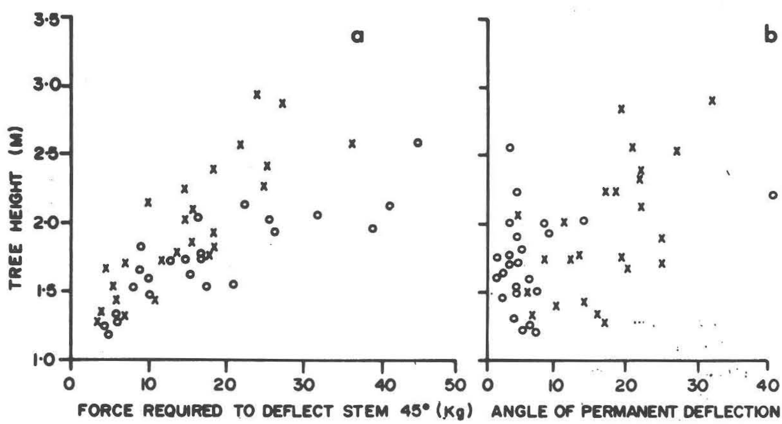

FIG. 1. A comparison of the stability of planted and naturally established lodgepole pine in a plantation near Quick, B. C.

(a) The resistance of planted (x) and naturally established (o) trees to being pulled over to an angle of 45° as measured with a spring balance attached to the stem approximately 30cm from the base. (Note. The data sugest an increasing difference in stability between planted and naturally established trees with increasing tree size. This interpretation is not justified, however, since the rigidity of the lowermost part of the stem increases with tree size. Thus, although all of the trees were pulled over to the same angle, a greater part of the deflection was accomodated by bending in the stem below the point at which the deflecting force was applied in the small trees than in the large ones. As a consequence, observations made on trees of different heights are not directly comparable.)

(b) The extent to which trees were permantly deflected from their original posture after being pulled over to an angle of 45° to the vertical and then released.

certain parts of New Zealand is due to the shallowness of the soil which prevents the development of the deep root system necessary for a firm anchorage in this species (Wendelken, 1955). Likewise, it is thought that instability in lodgepole and other species of pine planted in the United Kingdom is often due to frequent soil water-logging which prevents the development of a deeply penetrating root system (Busby, 1965).

However, when Clarke (1956) investigated the effect of a severe storm on young radiata pine in the Australian Capital Territory he found a large proportion of planted trees had been flattened while naturally established trees of a similar size were unaffacted. Similarly, it has been observed in British Columbia that, where planted and naturally established lodgepole pine seedlings occur together, the former are usually much less well anchored than the latter as judged either by the force needed to pull the trees over to an angle of 45° to the vertical, or by the extent to which trees are permantly deflected after being subjected to such a pulling test (Figs. 1a and b).

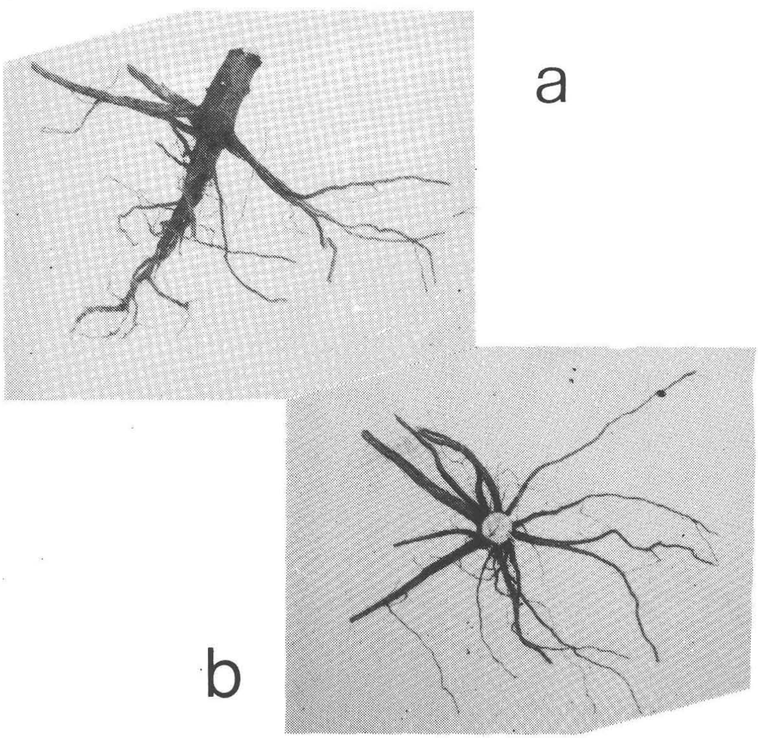

FIG. 2. The root of a 10 year old, naturally established lodgepole pine in profile (a) and from above (b). As with most naturally occurring lodgepole pine in British Columbia, this tree was growing in a well drained and relatively coarse textured mineral soil. The length of the tap root is approximately 30cm.

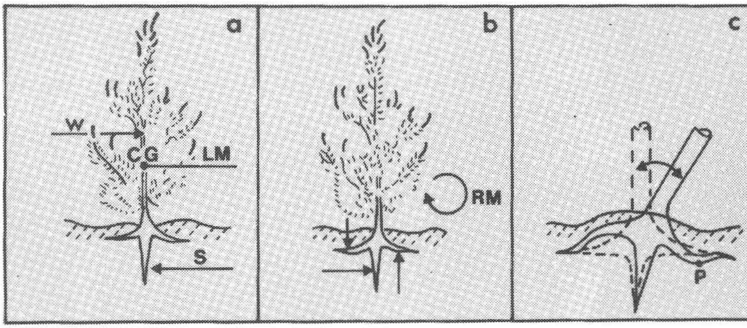

FIG. 3. The acquisition of, and resistance to, a turning moment by a pine seedling.

(a) A lateral force (W) acting on the crown, imparts to the tree a tendency to linear motion such that its centre of gravity (CG) moves in a line (LM) parallel to W. This tendency is opposed by forces in the soil (S) acting on the root in the direction opposite to that of the force W. Through the joint action of S and W the tree acquires a tendency to rotate about a point near the base of the stem.

(b) The arrow shows the direction and point of action of the main forces opposing a clockwise rotational moment (RW).

(c) Deformation in the root of a tree having a clockwise rotational moment. Because the soil above the left-hand lateral is more easily lifted than the soil underneath the right-hand lateral is compressed the tree tends to pivot about the point, P; the exact position of this point depends on how far along the root appreciable flexure occurs.

Thus, it appears that, at least in young planted pines, instability is mainly due to the fact of their having been planted.

The reason for the relative instability of planted trees becomes evident upon consideration both of the effect of planting, including that of nursery culture, on root form, and the relationship between the structure and function of a pine root system.

The lodgepole pine illustrated in Fig. 2 has a form which is typical of most naturally established pine seedlings (Aldrich-Blake, 1930; Bishop, 1962; Horton, 1958; Porter and Lamb, 1974; Preston, 1941). It has a well developed tap root which subtends an array of sturdy laterals orientated in the horizontal, or an oblique, plane.

Such a root is highly effective as a mechanical support as is attested by the firmness with which most naturally established pine seedlings are anchored. An indication of why it is effective may be obtained by reference to Figs. 3a, b and c.

Fig. 3a shows how the wind or any other force acting on its aerial portion imparts to a tree a tendency to rotate about a point near the base of the stem (except when the force acts on a line passing through the base of the stem — e.g. gravity). Tension in the windward-side lateral roots opposes this moment. Some rotation in the root system occurs, however, because of stretching in the windward-side laterals. This rotation is resisted by forces in the soil acting on the upper surface of the windward-side laterals, the windward-side of the tap root and the lower surface of the lee-side laterals (Fig. 3b). However, these forces are unlikely to provide a young tree with much support owing to the flexibility of its roots. Instead they will simply cause bending in the roots and deformation of the soil (Fig. 3c). Thus, the mechanical stability of a naturally established pine seedling with a root of the normal form is likely to depend primarily on the tensile strength of its lateral roots.

Tree pulling experiments support the conclusion that lateral roots of a young pine act as stays on the tap root main stem axis. For example, in the experiment of which the results are illustrated in Fig. 1b, the tree that was permanently deflected from its original posture to the greatest extent after being pulled over to an angle of 45° was a naturally established seedling that, on excavation, was found to have no lateral roots on the side opposite to that from which it was pulled. In other experiments it has been found that naturally established lodgepole pine seedlings lacking a tap root are also prone to acquire a leaning posture after being pulled over to an angle of 45° from the vertical, even though they possess a symmetrical array of lateral roots.

In contrast to that of a naturally established seedling, the lateral roots of a planted tree are not, at the outset, so disposed in the ground that they will necessarily be placed under tension by a turning moment acquired by the tree.

A bare root tree, for example, if it is well planted, has a bilaterally compressed root (Schantz-Hansen, 1945; Sutton, 1969). Thus, if a deflecting force is applied to the crown in the plane at right angles to the planting slit it will be opposed only by the very slight bending resistance of the roots.

And if not well planted, as is often the case, the roots of a bare root seedling may be unilaterally distributed in relation to the base of the stem (a so-called hockey-stick root), or they may simply be balled up in a planting hole that is too small for them (Gruschow, 1959; Hay and Woods, 1974; Wibeck, 1923). It is not to be expected that a root of either type will serve effectively as a mechanical support.

When first planted, the lateral roots of a container grown or mudpacked seedling (the latter having roots encased in a cylindrical mass of peat and clay or other material so that it may be dibble planted) are also ineffective in supporting the tree since they lie parallel to, or circle around, the tap root rather than extending out from it in the horizontal plane.

Thus, all the most common planting methods modify the form of a pine root system in a way that tends to reduce its effectiveness as an anchorage. What is more, the effect of planting on root morphology in lodgepole and other species of pine can persist for many years, if not throughout the life of the tree (Bergman, 1976; Gruschow, 1959; Hay and Woods, 1974; Schantz-Hansen, 1945; Sutton, 1969; Wibeck, 1923).

Besides influencing tree stability directly, there is some evidence that the effect of planting on root morphology can reduce stability indirectly. Reportedly this occurs when roots that have been balled together in planting, or which have come to encircle one another while growing in a container, restrict one another's growth as they increase in diameter (Bergman, 1976). It seems unlikely that such root strangulation occurs often, since contact between the roots of the same tree or species usually results in a graft being formed. And when this happens, there is a cessation of cambial activity where the roots make contact so that there is no tendency for the roots to grow into one another (Van den Driessche, 1958; Eis, 1972). Thus, it has been found in British Columbia that in the case of lodgepole pine and other species grown in small containers (Styro 2 containers — Sjoberg, 1974) the mass of roots forming the root plug graft together quite readily within several years of planting (author's unpublished observations).

However, there is at least one documented instance of tap root breakage in pot grown pines due, apparently, to a restriction of the growth of the tap root by a band of encircling laterals (Harris, 1978). Perhaps the explanation of this, and similar occurences, is that the trees were raised in relatively large containers so that by the time the tap root made contact with the lateral that had grown around the container wall, the roots had formed a relatively thick epidermal layer which delayed or prevented the formation of a graft.

The Significance of Juvenile Instability

Juvenile instability in planted pines is clearly of practical significance insofar as it causes trees to lose their upright posture, since trees that lean, or topple, develop a crooked stem. In some plantations the incidence of toppling can be very high. Besides Clarke's report (Clarke, 1956) of planted radiata pine seedlings in the Australian Capital Territory being flattened by a storm, there are reports (Booth and Mayhead, 1974; Edwards, Atterson and Howell, 1963) of a very high frequency of toppling in Scottish plantations of lodgepole, Corsican (*P. nigra* Arn.) and Scots pine (*P. sylvestris* L.) while, in New Zealand, basal bowing has occurred with a very high frequency in plantations of maritime (*P. pinaster* Ait.) (Sweet and Thulin, 1962), lodgepole and radiata pine (R. G. Brown, personal communication).

The number of trees in a plantation that develop a basal sweep depends, however, on the soil and weather conditions that prevail before the tree achieves a firm anchorage. An indication of the variation to be expected is provided by experience with lodgepole pine planted in the interior of British Columbia during the last 11 years.

In a provenance test plot established with transplant stock at Clucultz Lake near Prince George in 1972, the majority of trees had lost their upright posture by the spring of 1977 (K. Illingworth, personal communication). (Virtually all provenances were affected, although observations to be made in this plantation are expected to confirm Moss's report (Moss, 1971) of an effect of provenance on juvenile stability). Yet in a plantation at Genevieve Lake, less than 100 miles distant, only about 15% of the trees were found to have a basal sweep when examined in 1974. Furthermore, it appeared that, by then, the trees had become quite firmly rooted so that no further toppling is likely to have occurred there.

In all of the more than 40 other bare root lodgepole pine plantations in British Columbia that have been examined by the author between 3 and 8 years after establishment, many trees were found to be quite poorly anchored compared with naturally established trees of the same size. However, most, and in some cases all, of the trees in these plantations were standing upright at the time of observation. Thus, if soil and weather conditions remain favourable during the interim, it is probable that these trees will, like the majority in the Genevieve Lake plantation, achieve a firm anchorage without first developing a crooked stem.

In an examination of 7 of the province's oldest plantations established with container grown stock, great variation in the incidence of toppling was also observed. In a plantation on a deep organic soil near Boston Bar in the Vancouver Forest District, which was established in 1973, three quarters of the trees were leaning when the plantation was visited in the spring of 1977; one quarter of them, at an angle of more than 45° to the vertical. However, in the other 6 plantations established between 1970 and 1972 on mineral soils in the central interior of the province, the incidence of toppling averaged no more than about 10%.

But while most planted pines eventually become quite stable as a result of the processes of root elongation, branching, diameter growth and fusion they may not necessarily remain firmly anchored until maturity. In general, trees become less stable as they increase in size. Thus, if the effect of planting on the form and structure of a pine root persists throughout the life of the tree it may make the tree unduly susceptible to windthrow as it approaches rotation age.

Experience with lodgepole pine in British Columbia provides no basis for determining whether this is the case. However, Moss (1971) found that windthrow in different provenances of lodgepole pine in a 29 year old plantation at Wykeham in England tended to be correlated with the incidence of basal bowing. No investigation as to the cause of this relationship has been carried out. It seems possible, though, that asymmetry in the distribution of lateral roots which leads to toppling in young trees may result in windthrow later on. However, if this is the correct interpretation it is likely that it is the absence of, or lack of rigidity in, the lee side laterals which make for instability in older trees (Busby, 1965; Wendelken, 1966), rather than the absence of, or lack of strength in, windward side laterals as in young trees.

The Prevention of Planting-Induced Instability

Perhaps the only means of eliminating the adverse effects of planting on tree stability is to use planting methods which cause no persistent modification in the natural pattern of root morphogenesis.

One way of doing this would be to plant young seedlings which still have a capacity to initiate first order lateral roots. In the case of Corsican and lodgepole pine, if not of other species, this would mean planting seedlings no more than a few weeks old, since, in both cases, the capacity to initiate first order laterals is lost during the first season (Aldrich-Blake, 1930; authors unpublished observations). Whether adequate survival could generally be obtained using bare root stock of such an age is uncertain; although it is of interest to note that Anderson and Williamson (1974) observed quite high survival in freshly germinated coulter pine (*P. coulteri* D. Don) seedlings planted on a very dry site in southern California.

Instead of planting them as bare root stock, very young seedlings can be injection- or dibble-planted in a container. However, if satisfactory root development is to occur after planting, it is necessary to use a container that does not impede root development. In this respect, the split Styrene tube developed in Ontario may be less than satisfactory, although it is reported that, under certain circumstances, tubed pine seedlings develop a deeply penetrating root system with a well distributed array of laterals (Low and Oakley, 1975). Paper pots can also interfere with root growth after planting, although this might be largely prevented by the use of a paper pot that decomposes rapidly after planting (Segaran, Dojak and Rathwell, 1978).

The first bullet container developed for injection planting constitutes an extremely serious impediment to root growth (Anon., 1975; Waters, 1968). However, Walters has recently developed a perforated, 4-piece, plastic bullet, designed to come apart as the root system grows, that may prove to be more satisfactory (Anon., 1975). Another bullet design that may be suitable for planting very young pine seedlings is shown in Fig. 4. Consisting of a piece of wood having a pair of longitudinal slits at right angles to one another, it provides a central cavity for the tap root surrounded by 4 full length slots to permit egress of the lateral roots that will be initiated after planting.

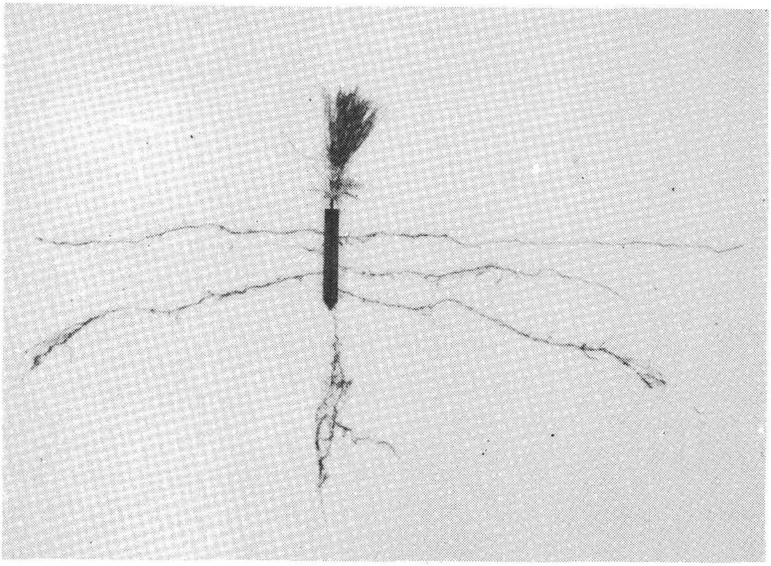

FIG. 4. A lodgepole pine seedling 12 weeks after planting in a slit-sided, wooden bullet. The seedling was planted 2½ weeks after emergence, just as the tap root reached the botom of the container. The elongation of lateral roots did not occur until after planting. Dimensions of the bullet are 1.2cm x 1.2cm x 9cm long.

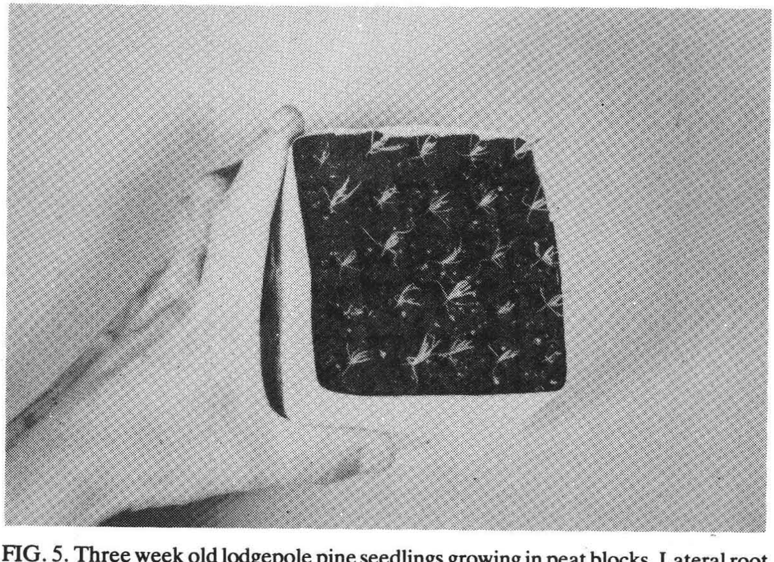

FIG. 5. Three week old lodgepole pine seedlings growing in peat blocks. Lateral root initiation in these seedlings has not yet begun. The blocks were manufactured by the author. However, a number of commercial concerns supply blocks of various materials for raising tree seedlings.

A different method of planting young seedlings is to raise them in blocks of a coherent rooting medium which can be dibble planted (Fig. 5). Several studies in the United States indicate that good survival can be obtained with 2 to 8 week old pine seedlings planted in this way (Barnett, 1975; White and Schneider, 1972).

If larger stock must be used, it may be possible to obtain a well formed root system by dibble planting seedlings that have been raised in containers coated with a root growth inhibitor to prevent lateral roots growing down and around the container walls (Furuta, Jones, Humphrey and Mock, 1972). In a trial with lodgepole pine seedlings raised in Styro-containers (Sjoberg, 1974) that had been dipped in exterior latex paint containing 0.1kg/l of basic cupric carbonate, the elongation of lateral roots was completely inhibited after contact had been made with the container wall (Burdett, 1978). However, the inhibited laterals resumed growth very quickly after planting. Consequently, the trees soon acquired an array of plagiotropic laterals growing straight out from the tap root like those of a naturally established tree (Fig. 6).

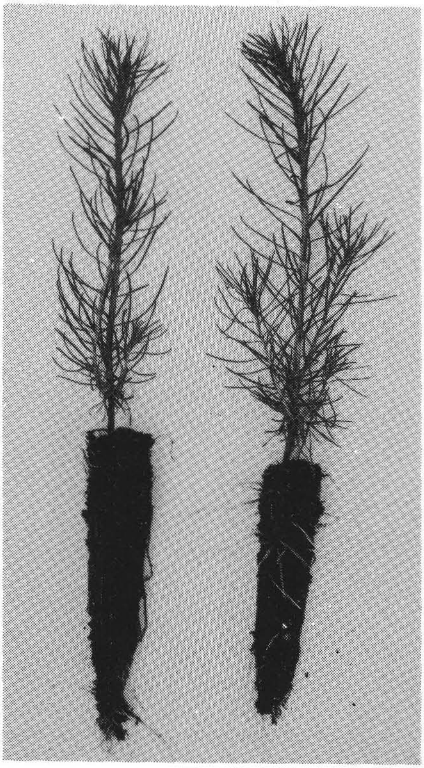

FIG. 6. Seedlings from copper painted (right) and unpainted containers one week after planting under warm, long-day conditions. The root plugs are approximately 11cm in length.

In contrast, root growth in seedlings from untreated containers was largely restricted to the elongation of lateral roots that had grown down the container wall to the tip of the root plug (Fig. 6).

If bare root stock must be planted, it is doubtful whether some persistent effect of planting on root form can be altogether avoided. However, studies in New Zealand with radiata pine indicate that box pruning of lateral roots to a length of approximately 5cm yields seedlings which are much less prone to toppling than are bare root trees produced in the usual way with lateral root pruning confined to one direction (along the length of the drills) only (Chavasse, 1978).

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